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4.2.2 Insulation

Insulation ranks as one of the best means of saving energy in buildings, reducing utility bills, and improving air quality. Insulation provides resistance to the flow of heat from a building's exterior to its interior, and vice versa. Thermal resistance is measured in R-value, the inverse of U-factor (the measure of heat flow through a material in Btu per square foot per hour for each °F difference in temperature). Insulation is primarily either loose-fill, batt, rigid boardstock, or foamed-in-place. Along with air barriers and vapor retarders, insulation controls the passage of sensible and latent heat and prevents condensation within wall and ceiling cavities. Though we take it for granted, only since the 1950s has insulation become widely available, inexpensive, easy to install, fire-retardant, resistant to pests, and able to retain these properties over time. It represents only a small portion of building costs, but insulation has a major impact on operating costs. So, selecting the proper insulation is one of the most economical and effective ways to reduce the operating costs and environmental impacts of a Federal facility.

Opportunities

Facility planners should specify R-values that minimize life-cycle costs for all new construction. Codes and standards dictate minimums, but it can be cost effective to use more. Improving the insulation in existing buildings, especially older ones, can also be cost effective and beneficial to occupants' health and comfort. Insulation can easily be added to attics or under floors, but retrofitting cavity insulation in walls is usually expensive and disruptive. It is less disruptive to add wall insulation on the exterior—for example, with an exterior insulation and finish system—giving a dilapidated exterior a new look. The best time to consider upgrading wall insulation is during a renovation. In reroofing, for example, insulation levels can easily be increased when exterior, low-slope insulation is being removed and reapplied (see Section 7.1.4, *Low-Slope Roofing*). Tapered insulation provides the desired slope to drains, increasing the roof membrane's life. Gasketing and caulking are integral to insulating envelopes for energy efficiency; they can be done either independently or during insulation upgrades.

Technical Issues

Selection issues for insulation include R-value performance (including changes over time), environmental impacts during manufacture, recycled content, whether HCFCs were used in manufacture, durability, waste generated, and potential health hazards. The insulation selected should conform to the relevant fire rating, pest-resistance, and product standards of ASTM and others. ASHRAE 90.1 specifies insulation requirements for various building envelope components, depending on heating degree-days and other factors.

R-value depends on the properties of the material, the thickness of the insulation layer, and the packing density. Though R-values per inch of thickness vary considerably, the table shows representative values for several common insulating materials.

R-VALUES FOR SOME COMMON INSULATING MATERIALS

Material	R-value per Inch Thickness (°F-ft^2-h/Btu/inch)
Mineral Fiber	3.3 to 4.3
Glass fiber	4.0
Perlite	2.8 to 3.7
Polystryrene	3.8 (expanded) 5.0 (extruded)
Cellular Polyisocyanurate	5.6 to 7.0
Cellulose, loose fill	3.1 to 3.7
Polyurethane, spray-applied foam	5.6 to 6.2
Cotton, batt	3.4

Source: *1997 ASHRAE Fundamentals Handbook;* cotton data from *Environmental Building News,* Vol. 9, No. 11 (November 2000).

Minimum recycled content of different types of insulation is specified in the recycled-content procurement guidelines of RCRA §6002. Insulation used in Federally funded projects exceeding $10,000 must meet these standards.

The ozone-depletion potential of rigid boardstock and foamed-in-place insulation has been reduced by manufacturing innovations and materials. The chlorofluorocarbons (CFCs) used as blowing agents in most foam insulation have been replaced either with HCFCs, which are about 10% as damaging to ozone, or with hydrocarbons, which do not deplete ozone. The HCFC-141b used in some polyisocyanurate and spray polyurethane should be phased out by Jan. 1, 2003; the HCFC-142b used in some extruded polystyrene (XPS) should be phased out by 2020, with a production cap in 2010. Ozone-safe polyisocyanurate and spray polyurethane appeared in the late 1990s.

Fiberglass insulation has a high recycled glass content and includes post-industrial recycled glass cullet from window manufacturing. An increasing percentage is recycled glass from beverage containers. Some fiberglass insulation batting is encapsulated in plastic wrap. This insulation is available without a phenol formaldehyde binder.

Mineral wool insulation is made from either iron-ore blast furnace slag (slagwool) or natural rock (rockwool). Mineral wool is fire-resistant and effective at blocking sound.

Cellulose insulation contains post-consumer recycled newspaper and fire-retardant borates and ammonium sulfate.

Cotton insulation is made from recycled cloth. Borates are added for fire- and pest-resistance.

Expanded polystyrene (EPS) insulation contains no ozone-depleting substances and can be made with recycled polystyrene. Though usually produced at low density—about 1 lb/ft^3 (16 kg/m^3)—higher density EPS is also available. In those cases, structural and R-value properties are closer to those of XPS. Below-grade EPS is widely used for insulated concrete-form products.

Spray-in open-cell polyurethane insulation is popular in lightframe construction. It can also be used for filling masonry block. Open-cell polyurethane contains neither ozone-depleting blowing agents nor formaldehyde.

There are diminishing economic returns as insulation thickness increases. Designers or facility managers should analyze life-cycle costs (LCC) to determine optimal insulation levels for minimizing LCC costs.

Thermal bypasses in the building can significantly reduce the effectiveness of insulation, which is why the R-value of wall insulation used with steel studs is significantly lower (see the table below).

Settling, dust, and moisture accumulation reduce the R-value of loose-fill and batt insulation, especially in vertical wall cavities. Skilled, careful installation should avoid or minimize problems.

Measures to protect both the installer and the insulation must be taken during any installation, and a continuous barrier (e.g., drywall) should be installed between the insulation and the occupied space to protect building occupants.

Be aware of the health hazards associated with asbestos. Asbestos is a proven carcinogen. It is prohibited in new construction; when found in existing buildings, it is usually left in place and encapsulated. When asbestos must be removed, all regulations and methods for removal, transportation, and disposal should be followed.

Moisture in the exterior wall cavity occurs when water is trapped in the cavity by impermeable surfaces. Condensation can occur if the dew point temperature occurs anywhere within the cavity. Managing moisture in the building envelope requires an understanding of the climate, the drying potential of wall cavities, and the interior space conditioning method. In northern (cold) climates, the interior side of wall cavities should be less permeable than the exterior side; just the opposite is true in warm climates with mechanically cooled buildings. Using rigid insulation on the exterior side of wall framing is one effective way to deal with moisture.

References

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IMPACT OF FRAMING ON WALL R-VALUES

Framing Material & Spacing	Insulation R-Value	Combined Insulation & Framing R-Value: Wood-Framed Walls	Combined Insulation & Framing R-Value: Steel-Framed Walls
2x4 16" on-center	R-11 (RSI-1.9) R-13 (RSI-2.3)	R-9.0 (RSI-1.6) R-10.1 (RSI-1.8)	R-5.5 (RSI-0.1) R-6.0 (RSI-1.0)
2x6 16" on-center	R-19 (RSI-3.3) R-21 (RSI-3.7)	R-15.1 (RSI-2.7) R-16.2 (RSI-2.9)	R-7.1 (RSI-1.2) R-7.4 (RSI-1.3)
2x6 24" on-center	R-19 (RSI-3.3) R-21 (RSI-3.7)	R-16.0 (RSI-2.8) R-17.2 (RSI-3.0)	R-8.6 (RSI-1.5) R-9.0 (RSI-1.6)

Notes: Assumes C-channel steel studs; steel-framing data from ASHRAE Standard 90.1; wood-framing values calculated using parallel-path method.

Source: *Environmental Building News*, Vol. 3, No. 4 (July/August 1994)